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Stabilization of a functional refreshment from mango nectar and yacon *(Smallanthus sonchifolius)* through spray drying encapsulation

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ABSTRACT:

Background: Yacon syrup (YS) may be implemented as a functional sweetener because of its concentration of fructooligosaccharides (FOS), which are sugars that are resistant to enzymatic hydrolysis in the human digestive tract. Additionally, health benefits related to the consumption of FOS have been reported, such as preventing constipation and reducing blood sugar and lipid levels in diabetic patients. Yacon is a tuber from the South American Andes region, and its nutraceutical effects have been researched.

Objective: The effect of YS as sweetener in a Mango Nectar (MN) stabilized through SD (which is?) and encapsulated with maltodextrin and Arabic gum (AG) was evaluated as a natural and alternative beverage for diabetic patients.

Methods: A sequential experimental design was used. First, mangoes were characterized into three ripening stages, evaluating pH, TSS, WC, WA, and TTA of each stage. Then, four formulations of MN with YS with concentrations of 33.3, 66.6, and 99.9% yacon-to-juice ratio were evaluated according to the quantity of TSS, which were analyzed over the acceptance of untrained judges. Later on, the formulation with the best acceptance was chosen and evaluated based on the performance of the encapsulation of components through SD using maltodextrin and AG with a 30% concentration and tricalcium phosphate (TP) with a 0.15% concentration. Lastly, the encapsulation process with maltodextrin with a 30% concentration was analyzed at temperatures of 100, 105, 110, and 130°C over the rehydration, evaluating WA, TSS, and Vitamin C.

Results: The mango with 12°Brix was selected for the formulation. The YS addition to MN generated significant differences ($p<0.001$) in the flavor because of the concentration with the addition of a 33.3% enhancing the flavor. As a result, the 33.3% concentration was selected for further testing. The final stage showed significant differences in the performance of the process of WA, TTA, TSS, and Vitamin C. Similar results were obtained regarding these components after the rehydration of the MN five days after storage. The retrieval of Vitamin C was not affected by the temperature, suggesting a favorable encapsulation.

Conclusion: The YS represents a potential nutraceutical sweetener, which may be used with concentrations around 33.3% over Tommy MN. The process of encapsulation through SD generates a product that is stable in storage and easily reconstructed.

Key words: fructooligosaccharides, inulin, micro-encapsulation, spray drying, yacon

INTRODUCTION

Yacon (*Smallanthus sonchifolius*, Asteraceae) is a tuber, perennial crop found in the South American Andes [1-3], consumed mainly as a ‘‘fruit.” The local population acknowledges it as both a food and medicinal plant. Tubers are used as a source for natural sweeteners and syrups suitable for people suffering from digestive problems [1] and/or renal disorders [4]. Additionally, these tubers contain antioxidants [1, 5, 6] and fructooligosaccharides (inulin-type oligofructans of the –(**β**2 -1) form) [1, 2, 4-6].

Yacon roots have these beneficial properties due to their fructooligosaccharide (FOS) content, which is an inulin-type fructan [7]. FOS are sugars found naturally in many types of plants. However, the FOS content is high in yacon roots [2]. FOS are able to resist the hydrolysis of enzymes in the upper part of the human gastro-intestinal tract, and because of this, yacon has a low caloric value for humans [8]. For this, yacon may be used as a natural sweetener for people suffering of diabetes or digestive problems [4, 9].

Noting that the food industry is currently interested in improving the nutritional benefits of their products without compromising their technological properties [7], it is possible to incorporate the use of YS into a nectar, which, according to the Colombian regulations, is a product obtained of the fruit juice with addition of water and sweeteners [10]. Still, due to it not being well-known, there are different processes that affect the quality of the partial or finished product during either its initial processing, storage, or distribution [11]. Since the majority of fresh food are highly perishable, adding value to it is possible through post-harvest engineering [12]. Thanks to microencapsulated ingredients, many products that were once considered technically unstable are now possible [13]. Encapsulation is a process for “trapping” active agents inside a carrier material, and it is a very useful technique for improving the provision of bioactive molecules and live cells contained within the food [13, 14]. One of the most important reasons for the encapsulation of active ingredients is to better the stability of the products during and after processing [15].

Spray drying is the most widely used process in the alimentary industry [14, 16] due to its flexible, continuous, and low-cost operation [15, 17]. Spray drying is the transformation of a food from a fluid state into a dried particle form by spraying the food into a hot-air drying medium [18]. Nevertheless, spray-drying technology requires adequate adjustments of operating conditions as well as for the composition of food solution [19] and the spraying conditions [20]. The products obtained present a potential advantage, which is that they can bypass the problem of the cold chains which are often associated with liquid food formulations. Avoiding the need for cold storage would make the transportation and distribution of the food much easier and cheaper [21].

Spray drying has been reported as a suitable technique for encapsularion of ingredients in food industry. The encapsulation of astaxanthin, by using milk protein and carbohydrate as the Wall materials, was generated with high efficiency, indicating the suability of these Wall matrices for encapsulating this biocompound [22]. Similar results has been reported in the encapsulation of limonene, where gum arabic, whey protein, and cassava starch byself (by self?) and mixtures indicated the effectiveness of the encapsulation process [23]. Maruf et al. reported that the maltodextrin could be used to enhance the antioxidant activities of functional food ingredients from purple sweet potatoes encapsulated by spray drying [17].

As stated above, the aim of this work was to evaluate the effect of the stabilization through spray drying of mango nectar sweetened with yacon root as an alternative for a functional refreshment drink that can be consumed by people suffering of diabetes or digestive problems.

MATERIALS AND METHODS

Raw Materials

Mango *Tommy atkins* was used in three different stages of ripeness along with regular yacon root. Both of them were bought in a local market. All the fruits were analyzed according their appearance, and the ones with unfavorable attributes were discarded.

Fruit Characterization

In order to determine Total Titratable Acidity (TTA), pH, Total Soluble Solids (TSS in °Brix), Vitamin C, Water Content (Wc), and Water Activity (WA), three fresh fruits were selected and macerated.

The TTA was measured according the AOAC 942.15A official method [24]; sodium hydroxide 0.1N was used for the neutralization until reaching a pH of 8.1; the results were expressed in percentage of citric acid. PH was determined following the AOAC 981.12 official method [24] by using the pH-meter JENWAY(Model370 pH/mV meter).

Total soluble solids were estimated following the AOAC 932.12 official method [25] by placing the liquid from the mashed fruit into a refractometer (Hand Held 500 HRS, Atago, Bellevue, Washington). The values of Vitamin C were determined according to the 2-Nitroaniline method [26] by using an spectrophotometer (GENESYS 10 S, model 335906-000)

The Water content was calculated by gravimetric method by using a forced circulation oven (Heraeus Model UT6120) and following the Cost 90 method [27]. Water activity was measured using the AOAC 978.18 official method [24] with a dew point water activity meter (Decagon model 7614 AQUALAB LITE).

Obtainment of yacon syrup and nectar formulation

The yacon syrup was obtained following the process reported by Rivera and Manrique (2005) [6]. Four different formulations of nectar were made using YS as a substitute for saccharose, the following proportions: 0% (control), 33.3, 66.6, and 99.9% of YS were used until to obtain a nectar concentration TSS of 13.5°Brix, following the Colombian NTC 5468 [28].

Sensory Analysis

The nectar formulations were evaluated in terms of acceptation of color, smell, taste, and texture of the product. For this, three samples of each treatment were selected and then placed in couples. The samples were coded at random using numbers of four digits.

For the sensory analysis, a five point hedonic scale was employed, and eight non-trained judges, who determined the acceptance level of the four parameters, evaluated the formulations. The analysis of the results was to carry out using the Kruskall-Wallis statistical test.

Spray Drying

The formulation with the best acceptation from the sensory analysis was submitted to a spray drying process conducted in a Spray Dryer (SPRAY DRYER INSTRUMENT YC-015, PILOTECH). The inlet temperatures were 100, 105, 110, and 130°C, with a pressure of 5 bar and an outlet temperature of 80°C. For the encapsulant material, maltodextrin and Arabic gum were used with a concentration of 30%, and 0.15% of tricalcium phosphate was added as an anti-compacting agent. Water activity and water content were evaluated on the finished product following the aforementioned process, as well as the yield of the process itself. The powdered nectar was stored in glass receptacles for five days.

Experimental design and statistical analysis

A randomized sequential experimental design was employed. For the first stage, an analysis of the three ripening stages of mango was carried through, thus selecting the mango with the higher TSS.

On the second stage, the YS addition in concentrations of 0, 33.3, 66.6, and 99.9% was evaluated. The formulation with the best acceptance after the sensory analysis was selected.

Following this, the formulation with the best acceptance was evaluated regarding the yield of the process of encapsulation through spray drying. The evaluated factors were coating agents with two levels (maltodextrin and Arabic gum), anticompactante addition (0 and 0.15%), and drying temperatures with four levels (100, 105, 110, and 130°C).

The effect of the factors in the three stages was determined by an analysis of variance (ANOVA) and a mean comparison with 95% significance, using the software STATGRAPHICS CENTURION XVI Version 16.1.11. All the determinations were made in triplicate.

RESULTS

Fruit Characterization

The results of the determination of TTA, pH, TSS, WA, and WC are shown in Table 1.

Total Titratable Acidity in the mango (or mangoes?) showed results between 0.97 and 0.80% of citric acid with a tendency of decreasing as the ripeness stage increases; however, the differences found are not statistically significant ($p>0.05$). This behavior is consistent with values found on pH, noting that an increase according to the ripeness stage was shown with results of 3.01 for ripeness stage 1 and 3.80 for ripeness stage 3. The differences found are not significant.

In general, an increasing tendency of pH was observed, which is generated by the decline in acidity [29], and that can be caused due to the metabolism of organic acids[30], which are consumed in oxidative reactions in ripening [31]. These changes represent a ripeness indicator in fruits [32]; however, the results are not significant, which may be attributed to small differences in the ripening stages that were evaluated.

Table 1: Characterization of mango in three ripening stages and of commercial yacon root

Treatment	TTA	pH	TSS	WC	WA
M1	0,97 a	3,01 a	8,46c	88,80 a	0,98 a
M2	0,94 a	3,14 a	10,45b	87,98 a	0,98 a
M3	0,80 a	3,80a	11,92 a	87,38 a	0,98 a
Y	0,05b	6,16b	14,18d	86,02 a	0,97 a

a-b Mean values (n = 3) with the superscript alphabets in each column are significantlydifferent ($p < 0.05$). TTA, Total Titratable Acidity; TSS, Total soluble solids; WC, Water content; WA,Water activity.

For yacon, a pH of 6.16 was found, which indicates that it is not an acidic fruit. This is reflected in the TTA results found (0.05%).

Regarding TSS in the mango, the results showed significant differences ($p<0.05$) because of the ripeness stage's effect, with results from 8.49 up to 11.92°Brix for ripeness stages 1 and 3 respectively. These variations may be explained because of the metabolism of the fruit itself and also associated with the conversion of starch in glucose and fructose [33]. Yacon presented a 14.18°Brix concentration.

Siddiqu et al. (2013) report similar values of pH, TTA, and TSS to the ones found in this work.

Water activity has been a widely studied factor due to the effects on the quality and stability of food, being more influential than the amount of water present in the food. This property determines the microbial growth and different spoilage reactions of foods[34]. For the mango in the three ripening stages and the yacon root, the water content showed results raging between 86.02 and 88.80% and a water activity of 0.98 for mango and 0.97 for yacon. These results define the fruits as products with high humidity, given that the water activity is above 0.7 [35]. Therefore, these fruits are estimated to be vulnerable to chemical and biochemical reactions, as well as microbial growth. In order to mitigate these effects, the process of drying may be applied as an alternative for the prolongation of shelf life [36].

Sensory analysis

The acceptability of the appearance of color, smell, texture, and the test for the four formulations of nectar are presented in Figure 1. It can be observed that the evaluated factors, regarding the addition of yacon syrup to mango nectar, present a favorable effect on the appreciation of the judges, which shows that for none of the four parameters that a punctuation lower than the commercial one (checkpoint) was given. The differences found in color, smell, and texture were not statistically significant,; however, when it came to taste, it was found that the addition of 33.3% of YS enhanced the taste according to the acceptation given by the consumers; the addition of 66.6% did not present significant differences, and the concentration of 99.9% generated statistically significant differences. This may be because of the color (yellow) and firm texture of yacon, which is similar to mango *Tommy atkins*. A similar behavior was reported by Morais*et al.* (2014), who stated that in formulations of gluten-free bread, the addition of FOS from tubers enhanced the flavor of the products [37].

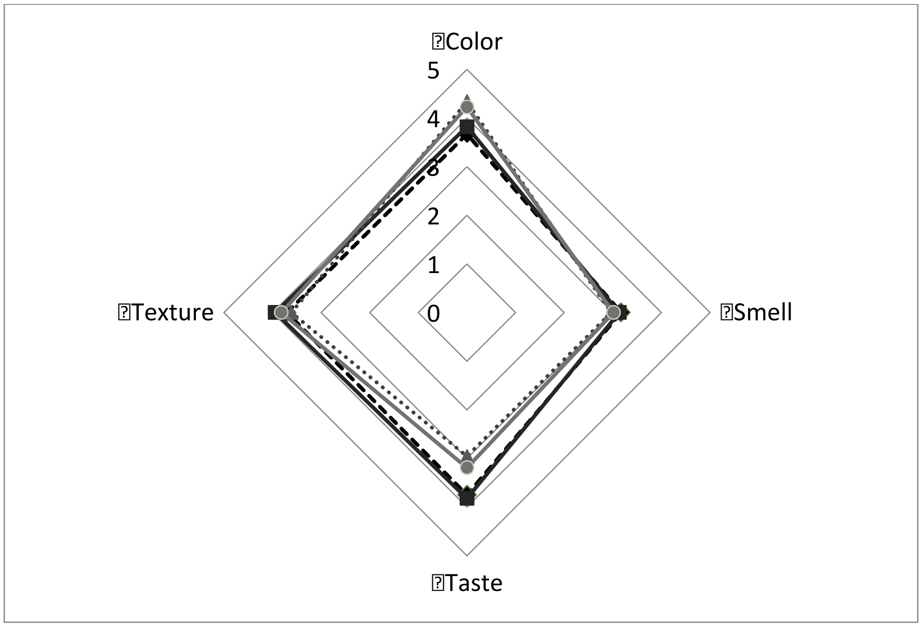

Figure 1: Acceptance of nectar formulations. •, checkpoint (0%); ■, addition of 33.3% of yacon syrup; ▲, addition of 66,6% of yacon syrup;●, addition of 99.9% of yacon syrup

Spray Drying

Included are the results of the treatments with maltodextrin, given that the treatments with Arabic gum with this concentration (30%) blocked the outlet of the equipment, resulting in analyzing lack of available product to analyze.

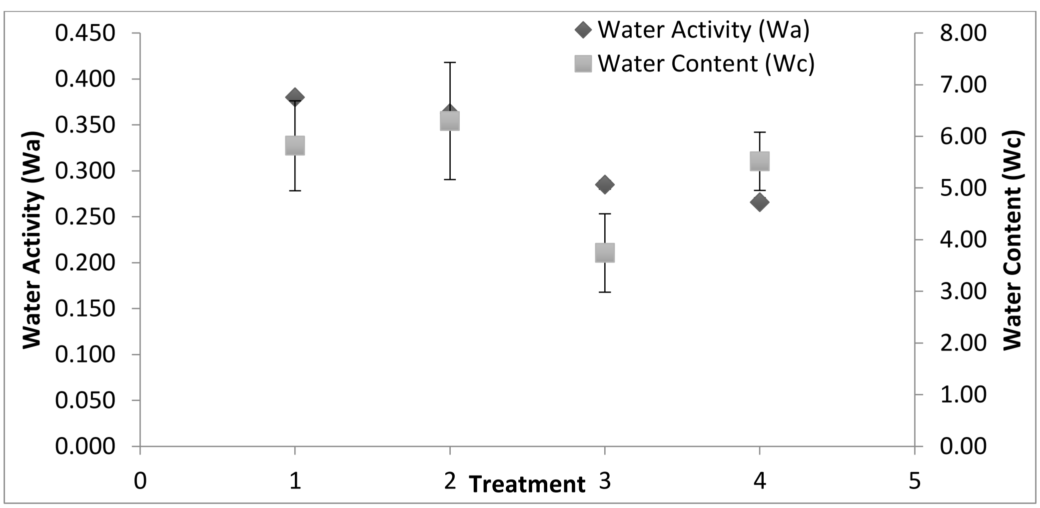

Figure 2: Water Activity and Water Content of the product after spray drying where 1 represents 100°C, 2 represents 105°C, 3 represents 110°C and 4 represents 130°C

Figure 2 shows the water content and water activity of the dry product. Water activity was below 0.4, which indicates that the product is not very susceptible to chemical reactions and microbial growth. The water content falls below 6.5%, which is due to the high inlet temperatures used in the process, and this defines the product as one of low humidity. This water contents are consistent with ones reported by Naddaf with contents below 6%[38].

The yield for the process ranged from 9.6% to 23.3%, showing a better performance at the temperature of 105°C (Figure 3). A similar performance was reported by Goula & Adamopoulos (2003), ranging from 13% to 26% in a tomato powder process. [39]

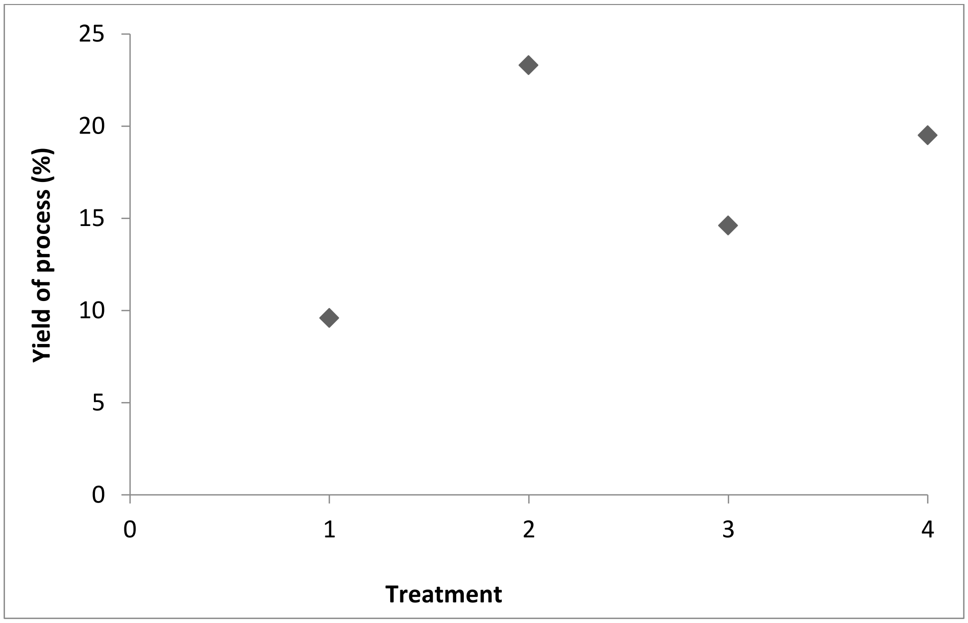

Figure 3: Yield results for the Spray Drying process, where 1 represents temperature 100°C, 2 represents temperature 105°C, 3 represents temperature 110°C and 4 represents 130°C.

Lastly, the reconstitution was easy, given that only some stirring was needed for obtaining a regular beverage.

CONCLUSION

The YS represents a potential nutraceutical sweetener, which may be used at concentrations around 33.3% over *Tommy atkins* MN. The process of encapsulation through SD generates a product that is stable in storage and easily reconstructed.

Abbreviations: Yacon syrup (YS), fructooligosaccharides (FOS), Mango Nectar (MN), Arabic gum (AG) , Total Soluble Solids (TSS), Water Content(WC),Water Activity (WA), Total Titratable Acidity (TTA), tricalcium phosphate (TP)

Competing Interests

The authors declare that they have no competing interests.

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